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Al-Gouhi

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(54) **REMOVING WATER DOWNHOLE IN DRY GAS WELLS**

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E21B 43/38	(2006.01)
E21B 47/047	(2012.01)

(52) **U.S. Cl.**

CPC ***E21B 43/128*** (2013.01); ***E21B 33/127*** (2013.01); ***E21B 43/38*** (2013.01); ***E21B 47/047*** (2020.05)

(58) **Field of Classification Search**

None

See application file for complete search history.

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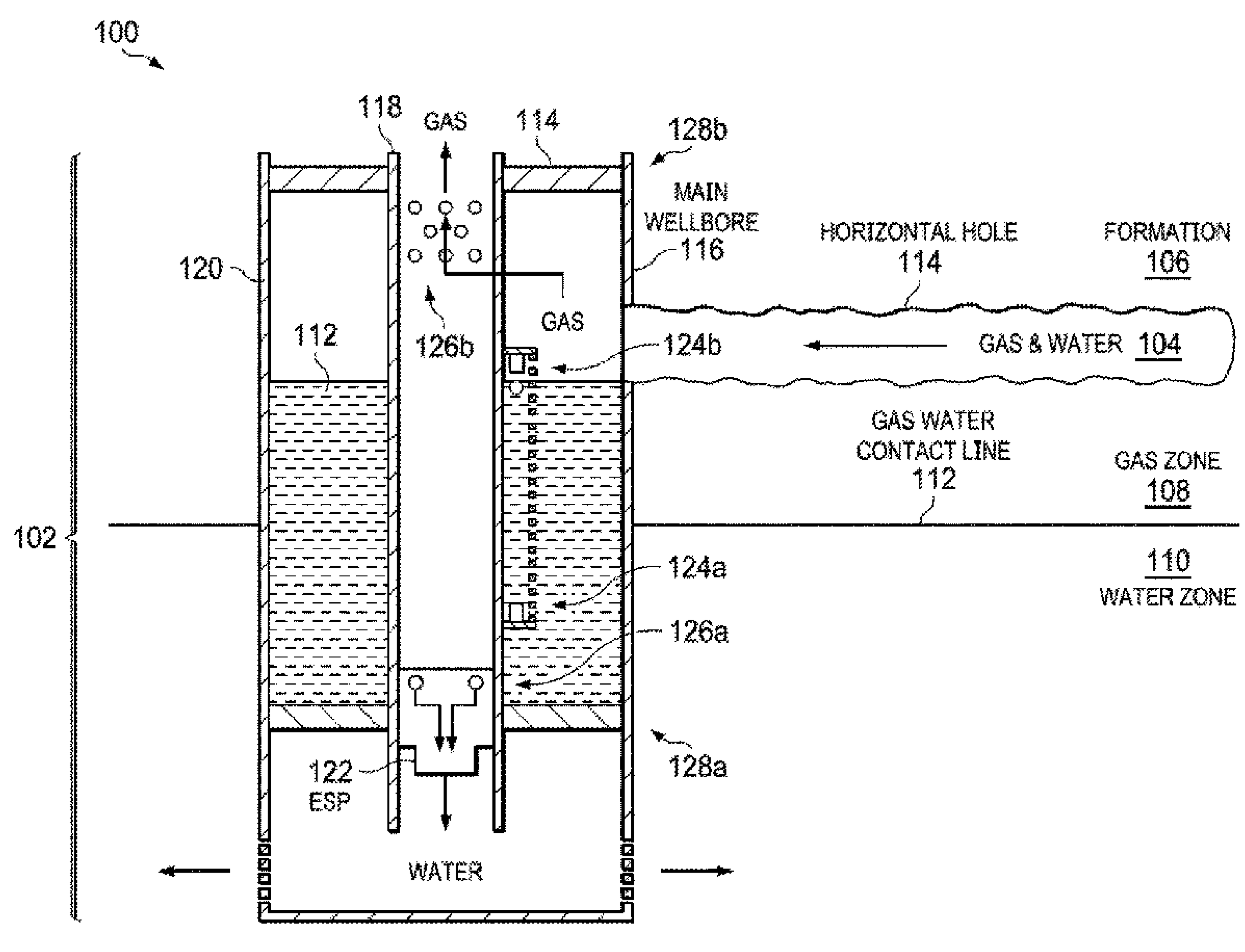
(57) **ABSTRACT**

A tool having a downhole conveyance, a first packer, a second packer, a pump, and a first and second sensor. The pump defines a plurality of inlets and an outlet, wherein the plurality of inlets is aligned with a first plurality of holes in the downhole conveyance, and the outlet oriented in a direction longitudinally opposite the first plurality of holes and the second plurality of holes. The second sensor is longitudinally separated further away from the first plurality of holes than the first sensor and configured to activate the pump when a water level is detected. The first sensor is configured to deactivate the pump when the water level is detected.

18 Claims, 2 Drawing Sheets



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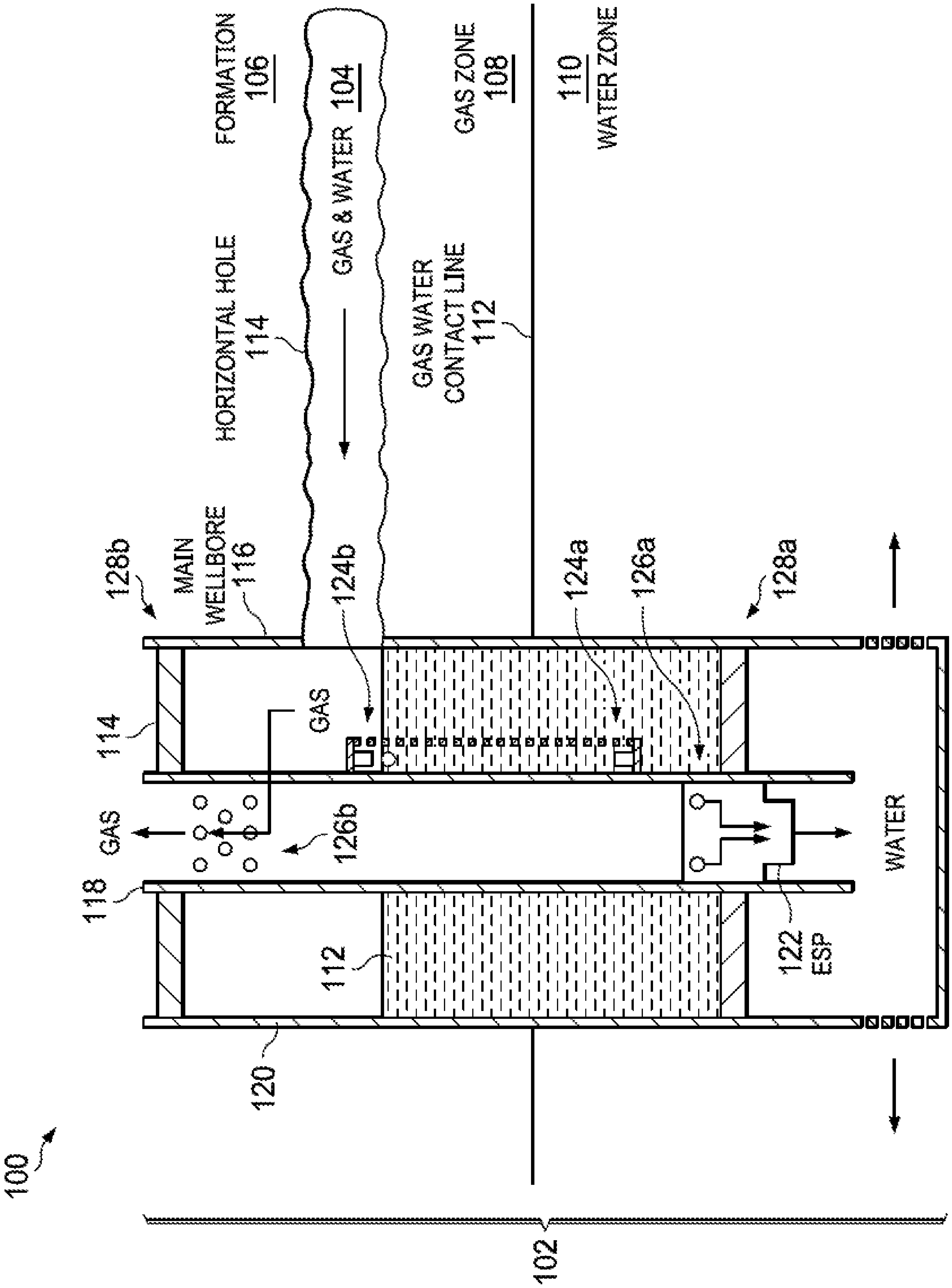
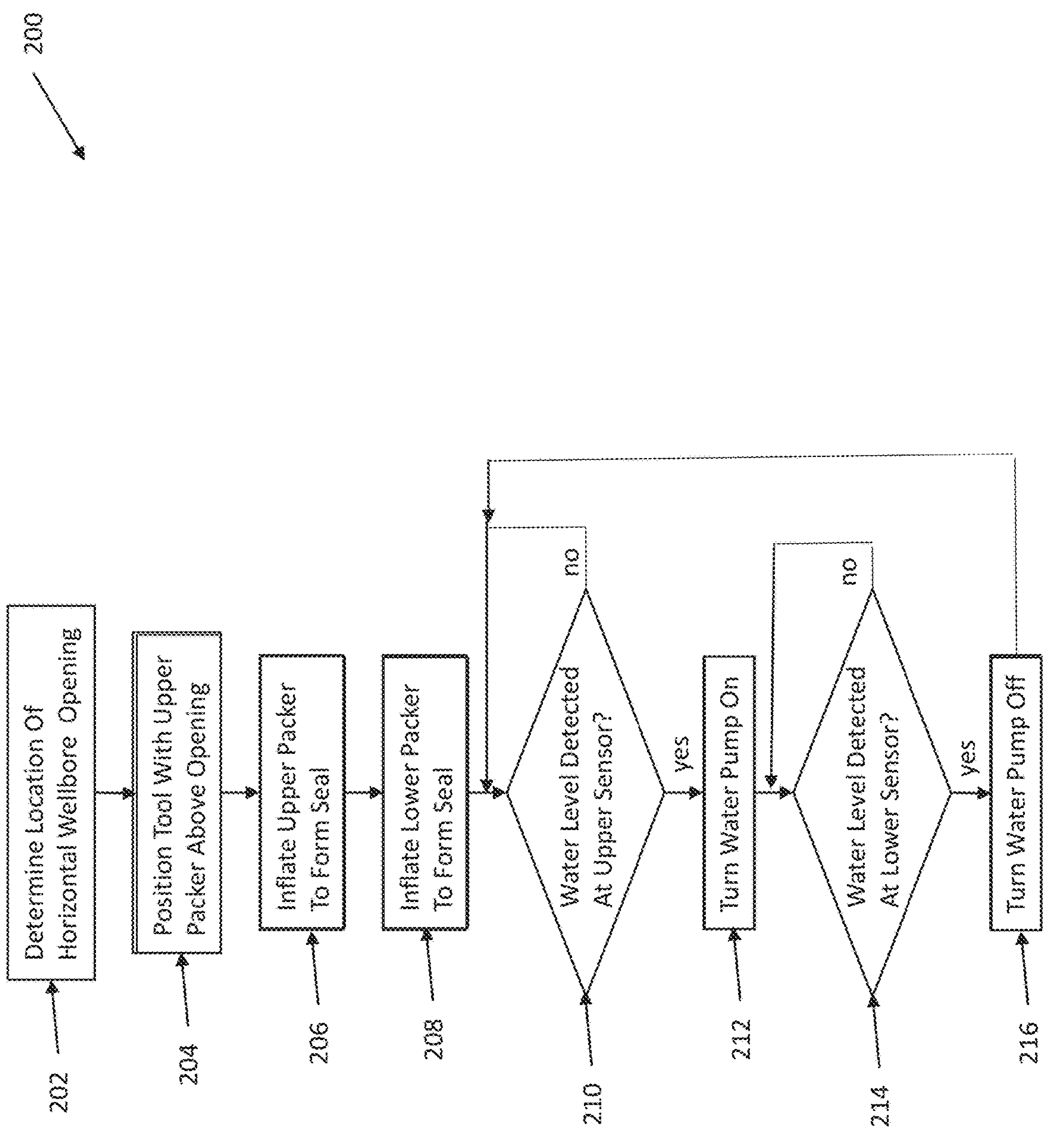

FORMATION 106
GAS & WATER 104
GAS ZONE 108
110 WATER ZONE
HORIZONTAL HOLE 114
GAS WATER CONTACT LINE 112
MAIN WELLBORE 116
128b
124b
124a
126a
128a
114
GAS
GAS
126b
118
112
122 ESP
WATER
120
100
102

FIG. 1

FIG. 2


200
Determine Location Of Horizontal Wellbore Opening
202
Position Tool With Upper Packer Above Opening
204
Inflate Upper Packer To Form Seal
206
Inflate Lower Packer To Form Seal
208
Water Level Detected At Upper Sensor?
210
no
yes
Turn Water Pump On
212
Water Level Detected At Lower Sensor?
214
no
yes
Turn Water Pump Off
216

REMOVING WATER DOWNHOLE IN DRY GAS WELLS

BACKGROUND

Waste water production with oil and gas is a challenge for the oil and natural gas industry. During the production of oil and natural gas, the oil and natural gas sometimes also includes water. The water produced through wells can originate from the hydrocarbon bearing zones, from aquifers that are near the hydrocarbon bearing zones, or from water that is injected downhole. Various chemicals are sometimes also mixed with the injection water to improve the reservoir sweep efficiency. When produced at the surface, this mixture of water and at least one of oil or gas can create a concern from an environmental standpoint.

In previous solutions, hydrocarbons and water are produced and separated at the surface. In wells that are drilled in to mature reservoirs, the water-cut can become extremely high, reducing the economic viability of the well, sometimes resulting in abandonment of wells. Other existing solutions include blocking the water encroachment by mechanical means, chemicals, controlled production, or some combination of these approaches. Such solutions, however, often adversely compromise the oil production capacity of wells.

SUMMARY

A tool having a downhole conveyance, a first packer, a second packer, a pump, and a first and second sensor. The pump defines a plurality of inlets and an outlet, wherein the plurality of inlets is aligned with a first plurality of holes in the downhole conveyance, and the outlet oriented in a direction longitudinally opposite the first plurality of holes and the second plurality of holes. The second sensor is longitudinally separated further away from the first plurality of holes than the first sensor and configured to activate the pump when a water level is detected. The first sensor is configured to deactivate the pump when the water level is detected.

The details of one or more implementations of the invention are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the invention will be apparent from the description and drawings, and from the claims.

DESCRIPTION OF DRAWINGS

FIG. **1** is a schematic illustration of a wellbore system that includes an example implementation of a formation-water removal tool.

FIG. **2** is a flow chart illustrating an example method for removing water downhole in a dry gas well, in accordance with some implementations of the present disclosure.

Like reference symbols in the various drawings indicate like elements.

DETAILED DESCRIPTION

The present disclosure describes a formation-water removal tool that is operable to remove formation water produced by a one wellbore and inject the formation water into an intersecting wellbore. For example, the tool can inject formation water from a horizontal wellbore into a main wellbore below the location of the horizontal wellbore. The tool, in some aspects, includes tubular conduits affixed to each other and positioned in a wellbore with wellbore

seals such as packers. Water from the subterranean zone collects in the annulus formed between tubular conduit and casing and between the wellbore seals. When the water level reaches a predefined level, a pump pumps water from the annulus into the wellbore through holes in the tubular conduit. In doing so, the tool can eliminate, minimize, or otherwise reduce the amount of formation water produced at the surface of the wellbore along with the gas. For example, the tool can be used in a dry gas well and utilize the main wellbore to collect the formation water produced from a horizontally wellbore in the dry gas reservoir. In some instances, the reservoir pressure is above the dew point pressure, which can eliminate or otherwise reduce condensate produced at the surface.

FIG. **1** is a schematic illustration of a wellbore system **100** that includes an example implementation of a formation-water removal tool **102**. Generally, FIG. **1** illustrates a portion of a wellbore system **100** according to the present disclosure in which the formation-water removal tool **102** can receive formation water and gas **104** from a formation **106** including a gas zone **108** and a water zone **110** and removes formation water **112** to produced gas **114** at the surface. In some aspects, a main wellbore **108** receives the formation water **112**, and the formation water **112** enters the water zone **110**.

The formation-water removal tool **102**, in some aspects, may direct the flow of water into an annulus formed in the wellbore **116**. One or more pumps can pump the water from the annulus into a portion of the wellbore below the formation-water removal tool **102**. The gas **114** can flow through a separation tubular to the surface. In some instances, the formation-water removal tool **102** can produce the gas **114** at the surface independent of pumps at the surface which are typically needed for water separation.

As illustrated in FIG. **1**, an implementation of the wellbore system **100** includes a downhole conveyance **118** that is operable to convey (for example, run in, or pull out or both) the formation-water removal tool **102** into the wellbore **116**. Although not shown, a drilling assembly deployed on the surface may form the wellbore **116** prior to running the formation-water removal tool **102** into the wellbore **116** to a particular location in the formation **106**. The wellbore **116** includes the formation-water removal tool **102** that extends from the terranean surface **102** and through one or more geological formations in the Earth including the formation **106**. The formation **106** includes the gas zone **108** and the water zone **110** and is located under the terranean surface. As will be explained in more detail below, one or more wellbore casings, such as an intermediate casing **120**, may be installed in at least a portion of the wellbore **116**.

In some implementations, the wellbore system **100** may be deployed on a body of water rather than the terranean surface. For instance, in some implementations, the terranean surface may be an ocean, gulf, sea, or any other body of water under which hydrocarbon-bearing formations may be found. In short, reference to the terranean surface includes both land and water surfaces and contemplates forming and developing one or more wellbore systems **100** from either or both locations.

In some aspects, the downhole conveyance **118** may be a tubular production string made up of multiple tubing joints. For example, a tubular production string (also known as a production casing) typically consists of sections of steel pipe, which are threaded so that they can interlock together. In alternative aspects, the downhole conveyance **118** may be coiled tubing. Further, in some cases, a wireline or slickline conveyance (not shown) may be communicably coupled to the formation-water removal tool **102**.

In some implementations of the wellbore system **100**, the wellbore **116** may be cased with one or more casings such as casing **120**. In some implementations, the wellbore **116** may be offset from vertical (for example, a slant wellbore). Even further, in some implementations, the wellbore **116** may be a stepped wellbore, such that a portion is drilled vertically downward and then curved to a substantially horizontal wellbore portion. Additional substantially vertical and horizontal wellbore portions may be added according to, for example, the type of terranean surface **102**, the depth of one or more target subterranean formations, the depth of one or more productive subterranean formations, or other criteria. For example, a horizontal well that intersects the main wellbore **116** can produce the water and gas **104**.

In the illustrated implementation, the formation-water removal tool **102** includes the tubing **118**, an electric submersible pump (ESP) **122**, a lower sensor **124***a*, an upper sensor **124***b*, a lower seal **128***a*, and an upper seal **128***b*. The tubing **118** includes lower openings **126***a* vertically lower than upper openings **126***b*. In some implementations, the lower openings **126***a*, the upper openings **126***b*, or both can be holes, slots, other appropriates shapes, or a combination thereof without departing from the scope of the disclosure. In addition, the lower openings **126***a*, upper openings **126***b*, or both can be arranged randomly, in a pattern, or a combination of both. In some implementations, the ESP **122** includes one or more inlets, and the lower openings **126***a* can be aligned with the one or more inlets of the ESP **122**. The upper openings **126***b* form a passage for the gas **114** to flow into the tubing **118** and then the terranean surface. The ESP **122** can inject the formation water **112** into the main wellbore **116** intermittently or continuously. In regards to intermittent rates, the volume of injected water can be based on the largest possible caging size, the smallest possible production tubing size, the maximum possible separation between the two sensors, as well as other appropriate parameters.

The lower seal **128***a* and the upper seal **128***b* are configured to form a seal between the tubing **118** and the casing **120**. In some implementations, the lower seal **128***a* and the upper seal **128***b* are packers such as inflatable packers or mechanical packers. In some implementations, the lower packer **128***a* and the upper packer **128***b* can be separated by 50 feet (ft), 100 ft, 150 ft, or greater. When sealed, the lower seal **128***a*, the upper seal **128***b*, the tubing **118**, and the casing **120** can, in some implementations, form an annulus that functions as a receptacle for the formation water **112**.

The lower sensor **124***a* and the upper sensor **124***b* detect the water level and turn the ESP **122** on and off. The lower sensor **124***a* is positioned above the lower openings **126***a* to shut off the ESP **122** before the water level is below the lower openings. This standoff distance assist in preventing gas from leaking into the pump intake or opening **126***a* The upper sensor **124***b* is located below opening to the gas zone **108** to turn on the ESP **122** before the water level rises above the lip of the opening In some implementations, the lower sensor **124***a* and the upper sensor **124***b* detects a water level when an object floating on a surface of the formation water **112** contacts either the lower sensor **124***a* or the upper sensor **124***b*. For example, when the upper sensor **124***b* detects contact with the floating object, the upper sensor **124***b* signals the ESP **122** to turn on. When the lower sensor **124***a* detects contact with the floating object, the lower sensor **124***a* signals the ESP **122** to turn off. In doing so, the formation-water removal tool **102** can prevent or otherwise reduce the production of formation water **112** at the surface and gas **114** passing to the main wellbore **116**.

FIG. **2** is a flowchart illustrating an example method **200** for removing formation water, according to some implementations of the present disclosure. For clarity of presentation, the description that follows generally describes method **200** in the context of the other figures in this description. However, it will be understood that method **200** can be performed, for example, by any system, environment, software, and hardware, or a combination of systems, environments, software, and hardware, as appropriate. In some implementations, various steps of method **200** can be run in parallel, in combination, in loops, or in any order.

At step **202**, a location of an opening to a horizontal wellbore is determined. As previously mentioned, a horizontal wellbore may drilled off the main wellbore and, in this case, the opening distance from the terranean surface is known. Other appropriate techniques can be used to determine the opening location without departing from the scope of the disclosure.

At step **204**, the formation-water removal tool is positioned with the upper packer above the opening and the lower packer below the opening. In FIG. **1**, the lower packer **128***a* is located below the opening, and the upper packer **128***b* is located above the opening.

At steps **206** and **208**, the upper packer and the lower packer are inflated, respectively, when the upper sensor is at or below the lower lip of the opening. Inflating the upper packer **128***b* above the opening and lower packer **128***a* below the opening forms an annulus where formation water can be collected and pumped into the lower portion of the main wellbore **116**. In addition, the location of the upper sensor **124***a* at or below the bottom lip can prevent or reduce formation water **112** from returning through the opening and interfering with gas production.

If the water level is detected at the upper sensor at decisional step **210**, then, at step **212**, the water pump is turned on. If not, the method **200** returns to the decisional step **210**. In regards to FIG. **1**, if the upper sensor **124***b* determines that the water level has reached that height, the upper sensor **124***b* signals the ESP **122** to turn on. As a result, the formation water **112** is pumped into lower portions of the main wellbore **116** and can return to the water zone **110**. In doing so, the water level can be maintained below the lower lip of the opening.

If the water level is detected at the lower sensor at decisional step **214**, then, at step **216**, the water pump is turned on. If not, the method **200** returns to the decisional step **214**. In regards to FIG. **1**, if the lower sensor **124***a* determines that the water level has reached that height, the lower sensor **124***b* signals the ESP **122** to turn off. As a result, the formation water **112** is stopped from being pumped into lower portions of the main wellbore **116**, and the formation water **112** begins to collect in the annulus again. In doing so, the water level can be maintained above the lower openings **126***a*.

A number of implementations of the invention have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the invention. Accordingly, other implementations are within the scope of the following claims.

What is claimed is:

1. A tool, comprising:

a downhole conveyance defining a first plurality of holes and a second plurality of holes longitudinally separated from the first plurality of holes;

a first packer affixed to an outer surface of the downhole conveyance and longitudinally separated further from the first plurality of holes than the second plurality of holes;

a second packer affixed to the outer surface of the downhole conveyance and longitudinally separated further from the second plurality of holes than the first plurality of holes;

a pump defining a plurality of inlets and an outlet, wherein the plurality of inlets is aligned with the first plurality of holes, and the outlet oriented in a direction longitudinally opposite the first plurality of holes and the second plurality of holes; and

a first sensor and a second sensor affixed to the outer surface and located between the first plurality of holes and the second plurality of holes, the second sensor longitudinally separated further away from the first plurality of holes than the first sensor and configured to activate the pump when a water level is detected, and the first sensor configured to deactivate the pump when the water level is detected.

2. The tool of claim **1**, wherein the downhole conveyance is a production string.

3. The tool of claim **1**, wherein the first packer and the second packer are inflatable packers.

4. The tool of claim **1**, wherein the downhole conveyance, the first packer, the second packer form an annulus when engaged with a downhole casing.

5. The tool of claim **1**, further comprising:

a porous housing defining an inner volume; and

a floatable object, wherein the floatable object, the first sensor, and the second sensor are located within the inner volume, and the first sensor and the second sensor detect contact with the floatable object.

6. The tool of claim **1**, wherein the pump comprises an electric submersible pump.

7. A method, comprising:

positioning in a wellbore a downhole conveyance defining a first plurality of holes and a second plurality of holes longitudinally separated from the first plurality of holes, wherein the wellbore intersects a horizontal wellbore;

engaging a first packer below an opening of the horizontal wellbore, the first packer affixed to an outer surface of the downhole conveyance and longitudinally separated further from the first plurality of holes than the second plurality of holes;

engaging a second packer above the opening of the horizontal wellbore, the second packer affixed to the outer surface of the downhole conveyance and longitudinally separated further from the second plurality of holes than the first plurality of holes;

in response to a second sensor detecting a water level, activating a pump defining a plurality of inlets and an outlet, wherein the plurality of inlets is aligned with the first plurality of holes, and the outlet oriented in a direction longitudinally opposite the first plurality of holes and the second plurality of holes; and

in response to a first sensor detecting the water level, deactivating the pump, wherein the first sensor and the second sensor affixed to the outer surface and located between the first plurality of holes and the second plurality of holes, the second sensor longitudinally separated further away from the first plurality of holes than the first sensor.

8. The method of claim **7**, wherein the downhole conveyance is a production string.

9. The method of claim **7**, wherein the first packer and the second packer are inflatable packers.

10. The method of claim **7**, wherein the downhole conveyance, the first packer, the second packer form an annulus when engaged with a downhole casing.

11. The method of claim **7**, wherein the first sensor and the second sensor are located within an inner volume of a porous housing, and the first sensor and the second sensor detect contact with a floatable object in the inner volume.

12. The method of claim **7**, wherein the pump comprises an electric submersible pump.

13. An apparatus, comprising:

one or more processors; and

a non-transitory computer-readable storage medium coupled to the one or more processors and storing programming instructions for execution by the one or more processors, the programming instructions instruct the one or more processors to perform operations comprising:

positioning in a wellbore a downhole conveyance defining a first plurality of holes and a second plurality of holes longitudinally separated from the first plurality of holes, wherein the wellbore intersects a horizontal wellbore;

engaging a first packer below an opening of the horizontal wellbore, the first packer affixed to an outer surface of the downhole conveyance and longitudinally separated further from the first plurality of holes than the second plurality of holes;

engaging a second packer above the opening of the horizontal wellbore, the second packer affixed to the outer surface of the downhole conveyance and longitudinally separated further from the second plurality of holes than the first plurality of holes;

in response to a second sensor detecting a water level, activating a pump defining a plurality of inlets and an outlet, wherein the plurality of inlets is aligned with the first plurality of holes, and the outlet oriented in a direction longitudinally opposite the first plurality of holes and the second plurality of holes; and

in response to a first sensor detecting the water level, deactivating the pump, wherein the first sensor and the second sensor affixed to the outer surface and located between the first plurality of holes and the second plurality of holes, the second sensor longitudinally separated further away from the first plurality of holes than the first sensor.

14. The apparatus of claim **13**, wherein the downhole conveyance is a production string.

15. The apparatus of claim **13**, wherein the first packer and the second packer are inflatable packers.

16. The apparatus of claim **13**, wherein the downhole conveyance, the first packer, the second packer form an annulus when engaged with a downhole casing.

17. The apparatus of claim **13**, wherein the first sensor and the second sensor are located within an inner volume of a porous housing, and the first sensor and the second sensor detect contact with a floatable object in the inner volume.

18. The apparatus of claim **13**, wherein the pump comprises an electric submersible pump.

* * * * *